Radiation Physics

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Introduction:

X-rays were discovered in 1895 by ***Wilhelm Conrad Roentgen*** who was a Professor at Wuerzburg University in Germany. Working with a cathode-ray tube in his laboratory, Roentgen observed a fluorescent glow of crystals on a table near his tube.

The tube that Roentgen was working with consisted of a glass envelope (bulb) with positive and negative electrodes encapsulated in it. The air in the tube was evacuated, and when a high voltage was applied, the tube produced a fluorescent glow. Roentgen shielded the tube with heavy black paper, and discovered a green colored fluorescent light generated by a material located a few feet away from the tube.

He concluded that a new type of rays were being emitted from the tube. This rays were capable of passing through the heavy paper covering and exciting the phosphorescent materials in the room. He found that the new rays could pass through most substances and casting shadows of solid objects.

Roentgen also discovered that the ray could pass through the tissue of humans, but not bones and metal objects. One of Roentgen's first experiments late in 1895 was a film of the hand of his wife, Bertha.

The generation, emission, and absorption of radiation involve atomic systems, that is, occurs at the subatomic level. So it is important to understand the atomic structure.

An appreciation for atomic physics is essential for the understanding of the uses and interpretation of the images produced by conventional radiography and the recent diagnostic imaging systems.

Composition of Matter

- ***Matter*** is the substance of which all physical things are composed.
  - It is anything that occupies space.
  - It is anything that has a mass and can exert force or be acted on by a force.
  - It occurs in three different states; solid, liquid or gas, depending on the degree of attraction between the atoms or molecules of which the matter is composed.
- ***Atom:***
  - The atom is the fundamental unit of an element.
    It cannot be subdivided by ordinary chemical methods, but may be broken down into smaller (subatomic) particles by special high energy techniques.

- ***Subatomic structure:***
  (a) <u>*Nucleus*</u>: (at the center) which is composed of two kinds of subatomic particles: the proton which is +ve charged and the neutron which is neutral. Since the neutrons have no charge, so the magnitude of the charge of the nucleus will depend on the number of protons $\rightarrow$ + ve charged.
  (b) <u>*Orbiting electrons*</u>: they are negatively charged.

- ***Orbits or shells:***
  - Electrons travel around the nucleus in curved paths termed <u>*orbits or shells*</u>. They are 7 in number (K, L, M, N, 0, P, Q) and are spaced at defined distance from the nucleus.
  - Electrons remain revolve in orbits because of the <u>*centrifugal force*</u> accompanying their motion in curved paths rapidly.
  - Electrons are not pulled into the nucleus because this centrifugal force is always equal to the <u>*electrostatic force of attraction*</u> (attraction between the positively charged nucleus and the negatively charged electrons) which keep the electron held in the atom.
  - Consequently, the amount of energy required to remove an electron from a given shell must exceed the electrostatic force of attraction between it and the nucleus.

<u>***Atomic number :***</u>

It is the number of protons (+ve charges) in the nucleus of an atom (which is equal to the number of electrons).

<u>***Atomic mass number:***</u>

It is the total number of protons and neutrons in a nucleus.

<u>***States of atom:***</u>

- **Ground (Normal, stable) state:**

Any atom in the normal or ground state is electrically neutral with equal numbers of protons (+v charges) and orbital electrons (-ve charges).

- **Excitation state:**

If an electron is displaced from an inner shell to an outer shell (i.e. to a higher energy level) the atom remains neutral but in an excited state.

- **Ionization state:**

It is the process by which an atom loses its electrical neutrality and becomes an ion either by addition or removal of an electron.

- If the electron is removed from the atom, the atom becomes a +ve ion. While the removed electron is called a –ve ion.
- While if an electron is added to an atom, the atom is a -ve ion and the other atom from which this electron was removed is a + ve ion.

<u>To cause ionization,</u> sufficient energy (more than that causing just excitation) must be applied to be more and to overcome the electrostatic force of attraction between the electron and the nucleus. *<u>X-rays are capable of causing this ionization of atoms.</u>*

Terminology

Radiology:	It is the science dealing with the diagnostic, therapeutic and research application of radiant energy in both medicine and dentistry for the purpose of diagnosis and treatment.
Roentgenology:	It is the science dealing with the diagnostic, therapeutic and research application of Roentgen rays only, in medicine and dentistry for the purpose of diagnosis and treatment.
Dental Roentgenology:	It is that branch of science dealing with diagnostic and research application of Roentgen rays in dentistry for the purpose of diagnosis of diseases.
Radiography:	It is the art of producing an image for a specific object by generating and directing x-rays on a sensitized plate.
Radiograph:	It is an image of an object produced on a sensitized film by use of x-rays.

<u>Radiation</u>

It is the emission, transmission and propagation of energy in space or in matter in the form of waves or particles.

<u>Types of radiation:</u>

1. Corpuscular or particulate radiation.
2. Electro-magnetic radiation.

<u>1. Corpuscular or particulate radiation:</u>

It is that type of radiation given off from radium, radioisotopes and during splitting of the atom.

<u>Properties of corpuscular radiation:</u>

They are minute particles, have a mass, have very high velocity, travel in straight lines, have a charge (except neutrons). They are not used in diagnostic dentistry but in therapeutic purposes.

<u>Examples:</u>

$\left.\begin{array}{l}\text{- Alpha } (\alpha) \text{ rays} \\ \text{- Beta } (\beta) \text{ rays}\end{array}\right\}$ emitted from radioactive isotopes.

- Subatomic structures resulting from splitting of atoms: protons, electrons, neutrons, and cathode rays (high speed electrons originating in a special device e.g.

x-ray tube).

2.Electro-magnetic radiation:

It is that type of radiation formed of units of pure energy which are propagated in the form of waves as a combination of electric and magnetic fields.

Properties:

- They are pure energy units (photons). The unit of photon energy is the electron volt (ev).
- They have no mass.
- They have no charge.
- They propagate in the form of waves.
- They travel at the same speed of light which is 186,000 miles /sec (3×10^8 meters/sec).
- They have a wave length (λ), frequency (υ) and velocity (C).

$$\underset{(3\text{x } 10^8 \text{ meter/sec})}{C} = \underset{\text{meters}}{\lambda} \times \underset{\text{Hertz (cycle /sec)}}{\upsilon}$$

λ : Distance between 2 crests or bottoms of 2 successive waves.

υ : Number of waves emitted /sec.

- The electromagnetic radiations differ in their power of penetration, which depends on the differences in their wavelength.

$\downarrow\downarrow \lambda$ (short) $\rightarrow \uparrow\uparrow \upsilon \rightarrow \uparrow\uparrow$ energy $\rightarrow \uparrow\uparrow$ power of penetration
$\uparrow\uparrow \lambda$ (long) $\rightarrow \downarrow\downarrow \upsilon \rightarrow \downarrow\downarrow$ energy $\rightarrow \downarrow\downarrow$ power of penetration

Electromagnetic spectrum:

It is arranged in an ascending order according to wavelength into:

1- Cosmic rays
2- γ - rays
3- X- rays $\rightarrow \lambda$ =0.1 – 1A° (A°= 10^{-10} m)

Ionizing radiation

4- Ultra – violet rays
5- Visible light
6- Infra-red rays
7- Micro- waves
8- Radio, radar, TV waves

Non- ionizing radiation

Roentgen Rays (X-rays)

X-rays are pure energy units belonging to the electromagnetic spectrum. They have a very short wavelength and can produce images of body tissues.

Properties :

Special properties :

1.They have a very short wavelength: Photons used in dental radiography have $\lambda \rightarrow$ 0.1A°.

As the $\lambda \downarrow\downarrow \rightarrow \uparrow\uparrow$energy$\rightarrow \uparrow\uparrow$ power of penetration.

The power of penetration depends also on: atomic number, thickness & density of the object and wavelength.

2.They have a selective penetration and absorption power: When the x-rays hit an object, certain interactions may occur:

- X- rays penetrate the object
- X-rays absorbed by the object
- X-rays deflected from certain objects

3.They affect photographic film emulsion:

Photographic film emulsion $\xrightarrow{\text{x-rays}}$ physical change (latent image)

Latent image $\xrightarrow{\text{By chemical processing}}$ Visible image

4. They can cause certain substance to fluoresce.

5. They cause ionization of atoms:

X-rays $\longrightarrow$ atom $\longrightarrow$ ion pairs $\longrightarrow$ harmful effect later on body cells.

6. They have biological damaging effect:

Somatic effects $\longrightarrow$ in the person himself

Genetic effects $\longrightarrow$ in the next generation

General properties:

1.They travel in straight lines, in a wave motion with the same speed of light.

2.They are invisible, can't be smelled, heard or felt.

3.They have no mass, no charge.

4.They can't be focused by a lens, can't be reflected by a mirror, can't be refracted in fluids, can't be deviated by a magnet and can only be deflected.

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